Multi-dimensional measurements of the parton shower in *pp* collisions at $\sqrt{s}$ = 200 GeV

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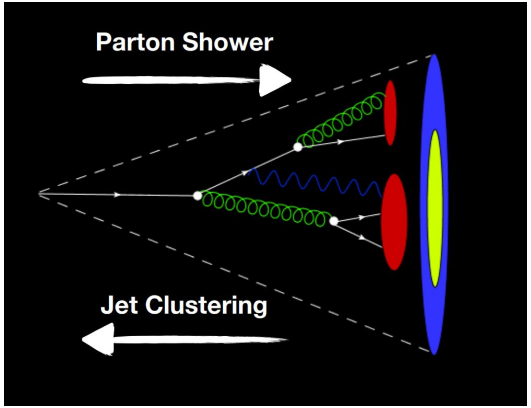
Motivation

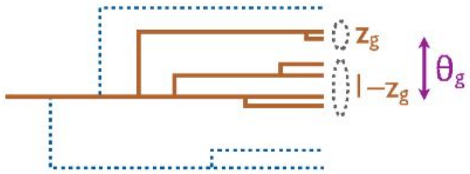
- Jets and their substructure contain information on parton shower (perturbative-QCD) and fragmentation (non-perturbative-QCD) processes
- Our goal is to access parton shower through experimental observables
- Two ways how to study the parton shower:
  - **Correlation between substructure observables at the first split**
  - **Evolution of the splitting kinematics as we travel along the jet shower**



Supported in part by the U.S. DEPARTMENT OF ENERGY Office of Science

SoftDrop

- Grooming technique based on removing soft wide-angle radiation
- Connects parton shower and angular tree



Larkoski, Marzani, Thaler, Tripathee, Xue, Phys. Rev. Lett. 119, 132003 (2017)

- Two STAR publications of substructure observables:
  - z_g and R_g at the first split:
    STAR, Phys. Lett. B, 811, 135846 (2020)
  - M (jet mass) and M_g (groomed jet mass):
    STAR, Phys. Rev. D, 104, 052007 (2021)

- **Shared momentum fraction z_g**

$$z_g = \frac{\min(p_{T,1}, p_{T,2})}{p_{T,1} + p_{T,2}} > z_{cut}\theta^{\beta},$$

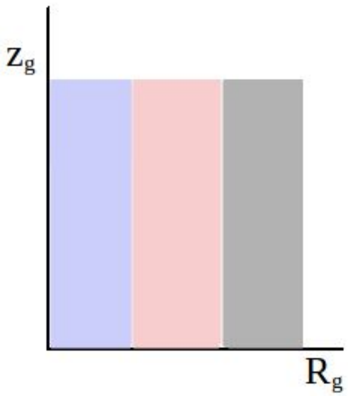
where $\theta = \frac{\Delta R_{12}}{R}$

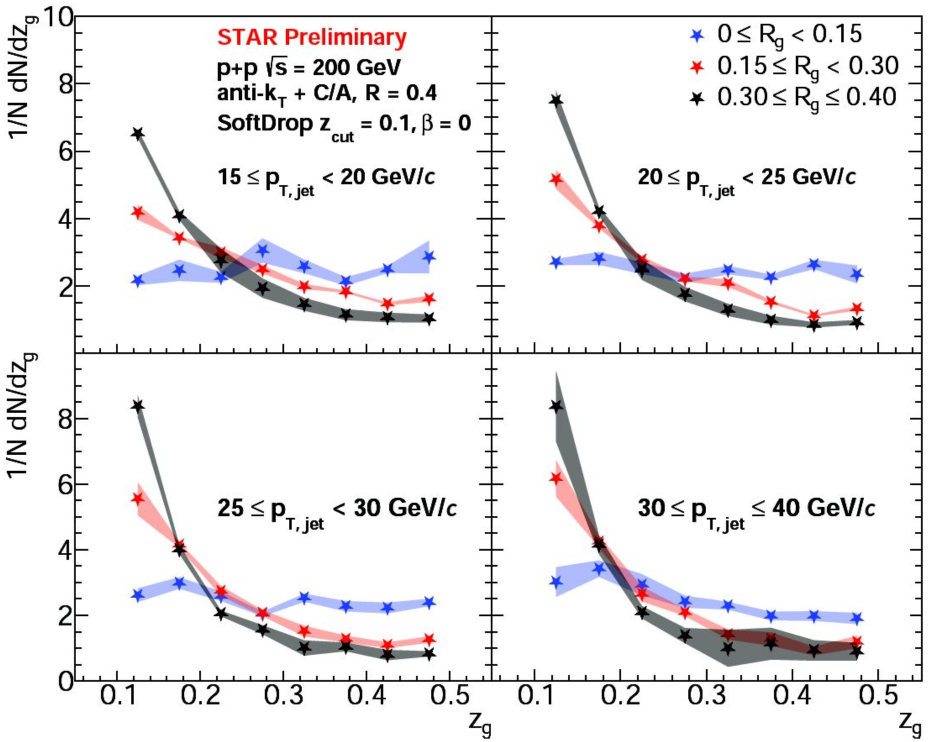
- $p_{T,1}, p_{T,2}$ - transverse momenta of the subjets
- z_{cut} - threshold (=0.1)
- β - angular exponent (=0)
- ΔR_{12} - distance of subjets in the rapidity-azimuth plane

- **Groomed radius R_g**
  - First ΔR_{12} that satisfies SoftDrop condition

Correlation between observables at the first split

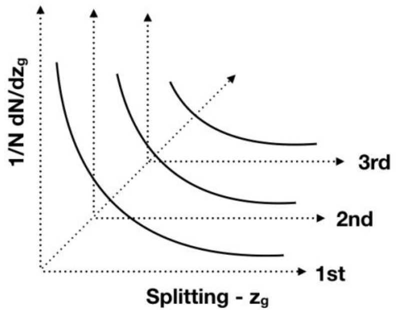
- z_g with respect to the R_g for different $p_{T,jet}$ bins
- Distributions change mildly with varying $p_{T,jet}$
  → R_g is the driving factor for the change in shape of z_g distributions
- Jets with large R_g have steeper z_g distributions
  → softer splitting is enhanced

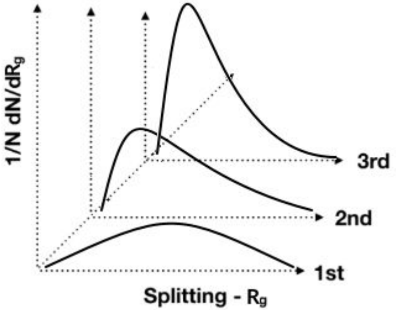


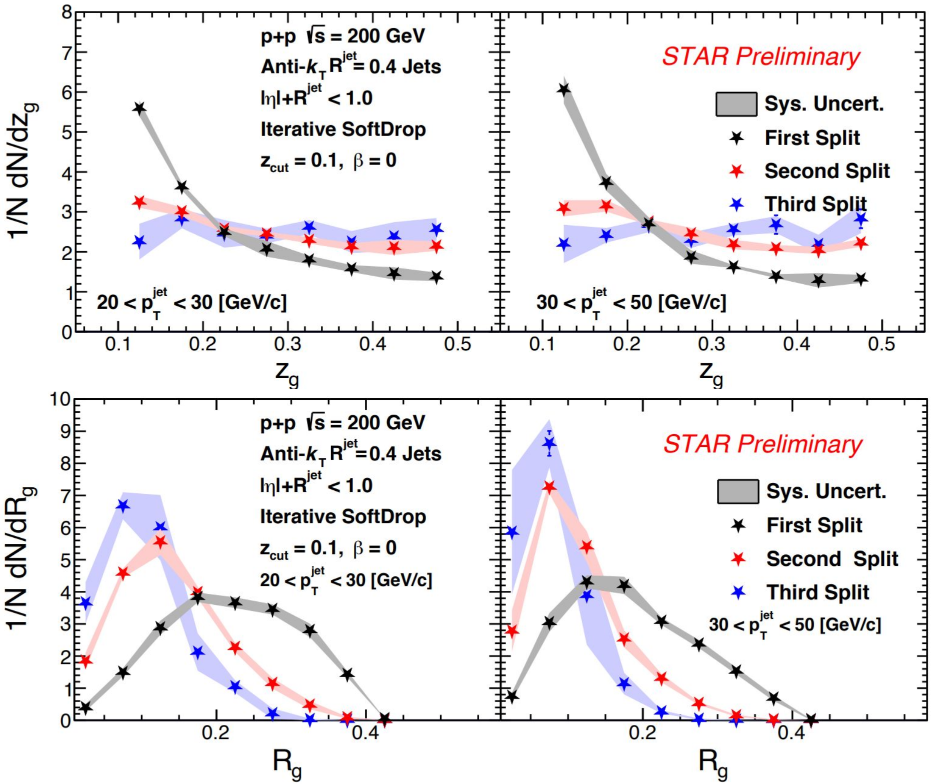


First, second and third splits

- z_g and R_g distributions at the 1st, 2nd and 3rd splits for various $p_{T,jet}$
- Going from 1st → 3rd split
  - z_g distribution becomes **flatter**
  - R_g distribution becomes **narrower**
  - collinear emissions are enhanced







Conclusion

- Data compared with simulations from different MC generators
- Leading order MC models describe the trend of the data

Correlation at the first split

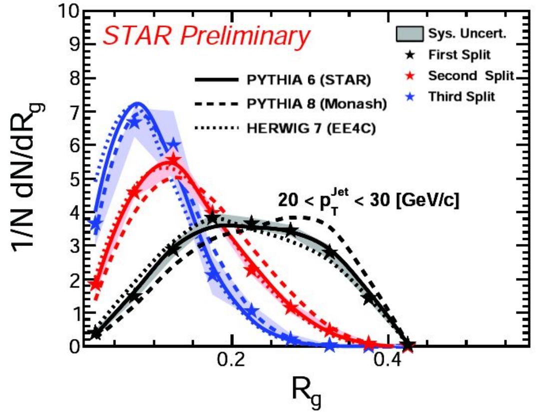
- z_g has a weak dependence on $p_{T,jet}$ and a strong dependence on R_g
- We can select significantly softer splits by selecting wider angle splits

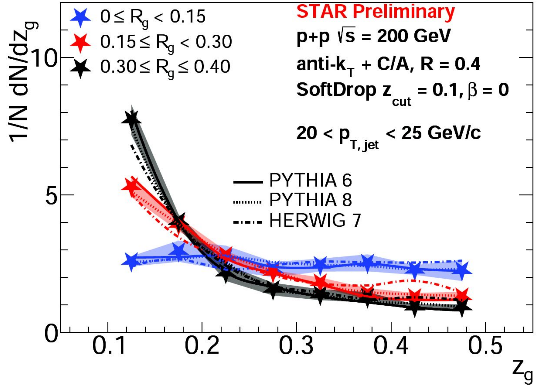
Splits along the shower

- Observed significantly harder/symmetric splitting at the third/narrow split compared to the first and second splits

Jet substructure measurements at RHIC energies allow to disentangle perturbative (early, wide splits) and mostly non-perturbative dynamics (late, narrow splits) within jet showers

Selecting on the split number along the jet clustering tree results in similar change in z_g distributions as selecting on R_g at the first split





The work has been supported by the grant LTT18002 of Ministry of Education, Youth and Sports of the Czech Republic.